Arc Performance Scores Core Concepts Guide

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Summary

Arc is a technology platform to measure, analyze, and score the operational performance of spaces, buildings, and places around the world. The Arc Performance Score serves as the foundation for multiple Leadership in Energy and Environmental Design (LEED) rating systems, including LEED v4.1 for Operations and Maintenance. The Arc Performance Score is a weighted composite of five performance categories, including energy, water, waste, transportation, and human experience. Category scores are based on measured performance, including metrics for greenhouse gas emissions, source energy consumption, potable water use, occupant satisfaction, and other factors. Metrics are normalized and compared to a global Reference Set composed of 3,103 projects. An Arc Performance Score of 100 indicates that a project is superior to all projects in the Reference Set, while a score of 0 indicates that it underperforms all projects in the Reference Set. A minimum score of 40 is needed to pursue LEED certification. Arc performance data provide an unprecedented view of the operational performance of LEED-certified projects. The data show that LEED Platinum projects have an average greenhouse gas emissions intensity of 1.14 metric tonnes per occupant per year -- 63% better than the average for LEED Certified projects. This reduction in emissions intensity is accompanied by a 19% improvement in average occupant satisfaction. Arc's combination of benchmark-based scores and performance indicators provide a powerful new market transformation tool.

Introduction

Arc is a technology platform to score the operational performance of spaces, buildings, and places around the world. Arc is part of the U.S. Green Building Council's family of market transformation tools. Arc Performance Scores serve as the foundation for multiple Leadership in Energy and Environmental Design (LEED) rating systems, including LEED v4.1 for Operations and Maintenance, LEED v4.1 for Existing Interiors, LEED Recertification, and LEED for Cities & Communities. Through October 2020, 3.9 billion square feet have been activated on the Arc platform. These projects are located in 127 countries, and they have more than 7 million occupants. The projects report emitting 115 million metric tonnes of greenhouse gases over the last 12 months. During 2020, approximately 19,000 individual users access the system to add, manage, or view performance data each 90-days. Going forward, Arc represents a core technology to support the use of operational performance in green building practice.

This paper explains Arc's approach to scoring the operational performance for spaces and buildings. The paper is divided into three sections: motivation for scoring, scoring approach, and scoring applications.

Motivation for Scoring

Arc emphasizes scoring as a tool to understand and communicate the operational performance of spaces and buildings. Arc's focus on scoring is motivated by three goals: simplification, differentiation and flexibility.

Simplification

Arc is based on the idea that the future of green building is rooted in measuring the operational performance of buildings, portfolios and communities. The idea is that measured, real-world performance will complement and, in some cases, replace documentation as the basis for recognizing high-performing green buildings. Ultimately, this is driven by the desire to ensure that green buildings consistently deliver real-world results.

In fact, we seek to define "green buildings" as facilities that deliver superior conditions for people and benefits to the environment. Arc helps advance this definition with metrics and scores encompassing human experience and multiple aspects of environmental performance. However, there is no single, direct measurement of this concept. Operationalizing this idea requires a level of aggregation and interpretation. Human experience in and around buildings reflects many performance dimensions,

including thermal comfort, daylight, odors, noises, vibrations, chemical exposures and much more. Similarly, we have many ways to measure environmental performance, including total energy use, peak demand, energy use intensity and more. Scoring provides a way to aggregate and simplify this kind of multifaceted data into something that can be readily understood and communicated understand, such as a 0-to-100 score.

There is both an art and a science to scoring. The art of scoring comes first. This may be surprising, since on the surface, scoring looks like math. However, scoring starts with specific goals and values. In the case of Arc, the goal is to use operational performance data to assess the degree to which spaces and buildings provide superior conditions for people while protecting the environment. Evaluating these concepts involves assigning weights to categories of project performance, such as energy efficiency, accessibility, or water conservation. By design, these categories are discrete concepts, such as greenhouse gas emissions, toxic exposure, or stormwater runoff. A scoring framework can aggregate performance across these factors. The relative importance of each issue can be analyzed in various ways, but weights for different categories are ultimately an expression of values, not science.

Once values have been expressed, we get to the science of scoring. The science involves selecting the most concise set of practical, measurable metrics to represent each area of performance. Further, it involves making a myriad of increasingly granular decisions regarding how metrics are defined, measured, analyzed and interpreted. For example, we need to decide whether we measure occupant satisfaction on a 0 to 5 or a 1 to 10 scale, or, alternatively, if we measure CO_2 concentration every year, month, day, hour, minute or second. Fortunately, we can analyze alternative strategies and look for strategies that best represent different dimensions of performance.

Ultimately, scoring mixes structural choices, such as the number of categories and their relative weights, with a myriad of small choices, e.g., the interpretation of individual metrics, to aggregate information. Scores do not create data. Rather, they interpret and simplify data to answer a specific question. In Arc's case, this means reducing five categories and more than a dozen measured variables into a simple 0-to-100 score that can be used to communicate performance.

Differentiation

The next critical issue is whether the score meaningfully distinguishes spaces and buildings. In the case of Arc, we are trying to differentiate spaces, buildings and places by the degree to which they actually provide superior conditions for people, while protecting the environment. This means that the value of an Arc Performance Score is reflected by the degree to which a high score (100) is meaningfully different from a low score (0).

The Performance Score ensures that a high-scoring space or building has low greenhouse gas emissions relative to similar projects with higher emissions. A project with a high overall Performance Score must also use less water, generate less waste and provide a more satisfying indoor environment than its peers. It is equally true that a low-scoring building has higher emissions and is relatively lower performing with respect to water, waste and human experience. These conditions are enforced by the structure of the Performance Score and the underlying interpretation of individual metrics.

Flexibility

The last essential element of scoring is flexibility. This might be a little less obvious. Arc provides a hierarchical structure linking multiple measures of operational performance to performance categories and ultimately to an aggregated score. One benefit of this structure is the ability to change individual metrics without reinventing the scoring system or disrupting the function of other performance categories.

For example, Arc has tools to assess transportation behavior. Today, the primary assessment tool is an occupant survey, and the metric is commuting-related greenhouse gas emissions. In the future it might be possible to assess transportation information based on a mobile app and potentially add a metric for time spent commuting. Arc's structure allows us to swap the assessment method and add an additional metric, while still expressing the transportation score in terms of 0 to 100. This allows for a "plug-and-play" relationship between individual performance metrics and their performance categories, while preserving the overall scoring structure. The structure provides the flexibility for the basis for scoring to evolve over time.

Scoring Approach

The overall Arc Performance Score answers one specific question: *How does a project compare to green buildings around the world green?* The Arc Performance Score is based on a three-level structure using five categories. It uses three types of information in addition to measured performance data for each category:

1. Normalizations for floor area, occupancy, schedule, and outdoor air temperature.
2. Key parameters, critically including the greenhouse gas emissions factor of grid-supplied electricity.
3. A Reference Set of green building projects around the world

Score Structure

The overall Arc Performance Score is a 0-to-100 metric. It is not limited to whole numbers and fractional scores are allowed:

Arc Performance Score [0-100] =
∑(Category Weight * Category Score)
Category Score [0-100] =
∑(Metric Weight * Metric Score)
Metrics Score [0-100] = f(reference set, normalizations, parameters)

Performance categories include energy (33%), water (15%), waste (8%), transportation (14%), and human experience (20%). These weights are based on priorities established in the LEED v4.1 rating system, and, consequently, these reflect the expressed values of the LEED Steering Committee and USGBC membership (USGBC 2015). The result is a composite 0-100 value for any project, each category, and each metric. Minimum data requirements to generate an Arc Performance Score for use with LEED include:

- ≥12 consecutive months of whole project energy consumption data
- ≥12 consecutive months of whole project water use data
- ≥1 survey for whole building waste generation and diversion from landfill per year
- ≥1 survey of occupant commuting per year
- ≥1 occupant satisfaction survey and measured carbon dioxide (CO2) and volatile organic compound (VOC) concentrations

Measured data and normalizations used for each category are described in more detail in the following section.

Arc applies two different strategies to interpret measured performance and generate metric scores.

1. *Reference Set Scoring:* Energy, water, and waste performance are evaluated by comparing a project to a "Reference Set". This is a collection of projects assembled to represent the range of energy, water, and waste performance observed for green buildings around the world.

2. *Absolute Scoring:* Transportation and Human Experience are evaluated based on scoring functions. Transportation is based on transportation-related emissions for average US commutes. Human Experience scores are based on mathematical interpretations of occupant satisfaction and measuring CO2 and VOC concentrations. These relationships are not based on the Reference Set.

Reference Set Scoring

Energy, water, and waste are scored based on intensities and comparisons to the Arc Reference Set. Metrics scored based the Reference Set include:

- Energy
    - Source energy
    - GHG emissions
- Water
    - Potable water consumption
- Waste
    - Waste generation
    - Waste diversion

Reference Set-based scoring for energy, water, and waste has several fundamental characteristics (Othman 2013). Scoring relationships in Arc are:

- Continuous – small changes in inputs produce small changes in output scores.
- Multi-dimensional – buildings being scored can be described by many attributes (size, occupancy, etc.)
- Monotone – Scores either always go up or always go down with an isolated change to each attribute.

- Interpolating – Scores are generated based on a set of reference buildings. For each reference building, the score produced by the spline is exactly the score requested in its input.

Taken together, the scoring process effectively provides a weighted average based on the "similarity" of a new project to projects in the Arc Reference Set (Reference Set), where similarity is based on floor area, occupancy, schedule, and outdoor air temperature. The Reference Set is not divided by property type. This represented a conscious decision to focus on continuous variables and avoid classification issues associated with complex, highly variable combinations of use types common among green buildings (Todd et al. 2013, Heidarinejad et al. 2014).

The Reference Set was assembled from available LEED project data with a specific emphasis on representation of building types and buildings representing extreme parameters (e.g., floor area, occupant density, energy intensity, etc.). The Reference Set includes a total of 3,103 projects. The fraction of projects with complete scorable data for each category varies. The Reference Set is static, and new projects using Arc are not currently being added to the Reference Set.

The inputs to each Reference Set-based score are presented in Table 1. These yield a category score between 0-and-100 based on the weighted rank in the Reference Set. The relationship between metrics and scores varies function of occupancy, schedule, floor area, and temperature. However, it is possible to describe several general characteristics of these scores:

- *Energy Score:* The maximum score of 100 requires measured performance near net zero energy *and* net zero carbon.
- *Water Score:* The maximum score of 100 requires very low use of potable water per occupant, e.g., <0.5 gallon per square foot per day.
- *Waste Score:* The maximum score of 100 requires very low waste generation and high waste diversion, e.g., <1 lbs per person per day with >95% diversion from landfill.

Arc provides tools to model Performance Scores for any combination of parameters and performance across all five categories.

Table 1. Energy, water, and waste are scored with respect to the Reference Set. Scores are based on the data, normalization, and parameters below.

	Energy Score	Water Score	Waste Score
Sub-Scores	Source energy intensity GHG emissions intensity	Potable water/occupant Potable water/floor area	Waste generation Waste diversion
Measurements	Liquid fuels, electricity, steam (min. monthly)	Whole project potable water consumption (min. monthly)	Waste generation intensity Undiverted waste intensity (1 survey/year)
Normalizations	Floor area, occupancy, schedule, outdoor air temperature	Floor area, occupancy	Occupancy
Parameters	Electricity emissions factor, site-to-source multiplier	None	None

Absolute Scoring

Arc uses a different scoring strategy for transportation and human experience. For these categories, Arc applies absolute mathematical functions (USGBC 2018). Categories and metrics include:

- Transportation
  - Average one-way GHG emissions per commute
- Human Experience
  - Occupant satisfaction
  - Indoor air quality: carbon dioxide (CO_2) and volatile organic compounds (VOC)

The Transportation scoring function is based on the distribution of US commuting. The distribution of commute-related emissions is roughly uniformly distributed between more than 20 pounds per one-way commute to less than 1 pound. Arc scores this relationship on a scale of 0 to 100.

Human Experience is scored based on the combination of two components: (1) perceived occupant satisfaction and (2) measured indoor air quality. Occupant satisfaction is based on an occupant survey. This requires a specified minimum response rate, and the score reflects both the mean and variance in occupant satisfaction. CO_2 and Total Volatile Organic Compound (TVOC) concentration are used as a proxy for indoor air quality with literature-based thresholds to establish scoring breakpoints. CO_2 scores are highest below 600 ppm CO_2 , and they decline rapidly after 1,000 ppm CO_2. TVOC scores are highest below 200 µg/m^3 decline quickly after 500 µg/m^3(USGBC 2018).

Table 2. Transportation and human experience are scored based on mathematical functions. Scores are based on the data, normalization, and parameters below.

	Transportation	**Human Experience**
Sub-Scores	Commuting emissions per occupant	Occupant satisfaction Indoor air quality
Measurements	Travel routes Travel distance Travel mode (min. 1 survey/year)	Occupant satisfaction and variance CO2 concentration (95% of time) TVOC concentration (95% of time) (min. 1 survey/year)
Normalizations	Regular occupants, visitors	Floor area, occupancy
Parameters	Electricity emissions factor, site-to-source multiplier	None

Score Applications

LEED Rating Systems

The Arc Performance Score is an input to several LEED rating systems, including LEED v4.1 O+M, LEED v4.1 for Existing Interiors, and LEED Zero. The Arc Performance Score serves as both a prerequisite and, effectively, a credit. For example, the LEED v4.1 for O+M Energy & Atmosphere prerequisite requires projects to generate a valid Arc Performance Score, and it references the Energy sub-scores for GHG emissions and source energy. Projects must demonstrate a minimum sub-score of 40 for both GHG emissions and source energy to earn an initial (minimum) 13 points toward LEED certification. Higher levels of performance earn more points up to a category maximum of 33 points. LEED v4.1 for O+M uses a similar approach for water and waste, again, with the Arc Performance Score serving as both a prerequisite and credit.

LEED Evaluation

The Arc Performance Score and, critically, its underlying metrics, provides opportunities to characterize relationships between key performance indicators and LEED certification levels. The data in Table 3 reflect performance for approximately 10,000 individual projects with a combined floor area of 2.7 billion square feet. The present presents a cross-tabulation of a selected set of metrics by LEED certification level.

Table 3. Relationship between Arc performance metrics and LEED v4 and v4.1 O+M certification levels (Source: Arc, data accessed December 2019).

	LEED Certified	LEED Silver	LEED Gold	LEED Platinum
mTCO2e/occupant/ year	3.05	2.65	2.11	1.14
Change in emissions/occupant	0%	-13%	-31%	-63%
mTCO2e/per commute/year	3.89	2.99	2.58	1.64
Change in emissions/commute	0%	-23%	-34%	-58%
Median occupant satisfaction	7.1	7.3	7.5	8.4
Change occupant satisfaction	0%	+4%	+7%	+19%

ENERGY STAR

The Arc Performance Score is often compared to the US Environmental Protection Agency's ENERGY STAR program for commercial buildings (ENERGY STAR 2018). Both systems provide 0-to-100 measures of operational building performance. However, the tools have different purposes, and they are best understood as distinct and complementary performance indicators.

ENERGY STAR the score is generated from a statistical representation of the US building stock based on the Commercial Building Energy Consumption Survey (CBECS). Consequently, ENERGY STAR scores can be interpreted as the rank of a building relative to a portion of the US stock. In contrast, an Arc Performance Score represents the weighted rank of a project relative to the Arc Reference Set. The Arc Reference Set was selected to represent the range of green building performance, not the US building stock. The relationship between the Arc Reference Set and the CBECs representation of the US building stock has not been fully analyzed.

The differences in objectives, formulation (e.g., normalizations), and, critically, comparison sets mean that Arc Scores are only partially correlated with ENERGY STAR scores. A linear regression between the Arc Carbon Score and ENERGY STAR has a r^2 of 0.34, and the Arc Source Energy Source has a r^2 of 0.40. These are statistically significant, positive relationships. However, there is significant variance between Arc Performance Scores and ENERGY STAR scores, and there is not a necessary relationship between them (i.e., there is no *a priori* expectation for correlation).

Conclusions

Arc Performance Score is a practical tool to understand and communicate the operational performance of space and buildings around the world. The Arc Performance Score prioritizes simplicity and global applicability. Its five performance categories also reflect USGBC's long-standing commitment to an integrative, multi-criteria definition for green buildings. Any project, anywhere in the world can generate an Arc Performance Score and compare itself to a sample of green buildings. This design allows for broad applicability, but it also has notable limitations.

The Arc Performance Score may not be sensitive enough to recognize globally small differences between buildings in a local area or over time. This means that significant improvements at a single facility may not be sufficient to generate changes in performance relative to Arc's global Reference Set. Further, the Arc Performance Score is only one possible interpretation of the underlying data. There are other valid and useful interpretations that could be used as the basis for scoring. For example, the same data could be used to evaluate compliance with local energy efficiency regulation or to inform a waste management program. It is important to recognize that the ability to answer these important questions is an underlying capability of the Arc platform and a benefit of using the Arc Performance Score as an entry point operational performance measurement and scoring.

The Arc Performance Score will continue to evolve as we encourage every green building to measure and improve real world performance. This will include incremental improvements, such annual updates to emissions factors, and, from time-to-time, the addition or removal of metrics or entire categories. These changes will be guided by Arc's commitment to recognizing leadership and long-term support for LEED as a global market transformation tool.

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